Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, DC 20554

In the Matter of

Petition for Declaratory Ruling Regarding	)	
Treatment of Rulemakings and Waivers	)	
Related to New Equipment and Services	)	ET Docket 13-259
at Frequencies Greater Than 95 GHz	)	

Comments of
Marcus Spectrum Solutions LLC

SUMMARY

Present FCC Rules prohibit nearly all commercial use of spectrum above 95 GHz -- a limit reached in an October 2003 decision. It is likely that this anachronistic prohibition is discouraging capital formation for products in services in this area while in countries that are our economic competitors a "state capitalism" model of spectrum policy is both facilitating capital formation through research cost sharing by the national government and coordinating wireless research policy in those countries with spectrum policy. The net effect is to disadvantage US entities in the global competition to advance wireless technology and introduce the most advanced telecom services.

The July 1, 2013 IEEE-USA petition in this proceeding seeks to address this problem by declaring technology above 95 GHz presumptively to be "new technology" in the context of Section 7 of the Communication Act. We support this petition.

In the 30 years since Section 7 was adopted the Commission has never identified a single new technology subject to its terms and has never even adopted procedures for dealing with such issues. The spectrum above 95 GHs is truly "green field" spectrum with no incumbent FCC regulatees. Protection of radio astornomy and other passive allocations as well as possible federal government users is an important issue, but can be accomplished with traditional NTIA coordination procedures. They do not need the present prohibition.

INTRODUCTION

Marcus Spectrum Solutions LLC (MSS) is the consulting practice of Michael J. Marcus, Sc.D., F-IEEE, a retired FCC senior executive who worked at the Commission nearly 25 years in both the spectrum policy and enforcement areas. His qualifications are well know to the Commission[1]. While at FCC he initiated and directed the 60 GHz rulemaking in Docket 94-124 and also initiated the 70/80/90 GHz rulemaking in Docket 02-146 and played a key role in it. He was recently awarded the 2013 IEEE Communications Society Award for Award for Public Service in the Field of Telecommunications.[2] These comments do not necessarily represent the view of any client and are being submitted purely in the public interest.

While the Commission's Table of Allocations[3] goes as high as 275 GHz, present FCC service rules stop at 95 GHz, a point reached in October 2003 in Docket 02-146. This lack of service rules then forbids the sale and use of equipment above 95 GHz except under the following narrow conditions:

- Use by the Federal Government entities authorized by the National Telecommunications and Information Administration[4]
- Experimental use in bands not having only passive allocations[5]
- Amateur radio use in certain bands[6]
- Industrial, scientific and medical (ISM) use at 122 -123 GHz and 244 - 246 GHz[7]

Thus anyone who develops product at a frequency greater than 95 GHz faces the requirement of a nonroutine FCC decision to get market access. This could be either a waiver proceeding[8] or a rulemaking

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1 FCC Press Release "FCC Engineering Michael J. Marcus Honored by Institute of Electrical and Electronics
2 http://www.comsoc.org/about/memberprograms/comsoc-awards/telecom/bios
3 47 C.F.R. §2.106
4 47 U.S.C. §§305,902
5 47 C.F.R. §5.85(a)
6 47 C.F.R §97.301
7 47 C.F.R. §18.301 These provisions only apply to narrowly defined ISM uses per 47 C.F.R 18.101(c) and not to other uses of these bands such as radar or unlicensed communications which are permitted in several lower ISM bands.
8 47 C.F.R. §1.925

proceeding and the expected time to resolution could easily be measured in years based on past experience,

The present hindrance to investment is quite real in this above 95 GHz technology area resulting from both the current prohibition and significant timeliness questions about how FCC will handle any request for a rule change permitting such use. Technology development is generally quite expensive and is usually dependent on private capital formation either within existing corporate entities or from external funding of entrepreneurs. Those making decisions on such technology development funding expect risk -- for all innovative technology is risky. But an additional layer of regulatory risk along with unknown regulatory delays for market access could make investment in >95 GHz technology unattractive compared to other possible investments without such high regulatory risk.

While serving as Chief, Wireless Telecommunications Bureau, Ruth Milkman, spoke on the FCC's spectrum goals with respect to making more spectrum available:

> Going forward we continue to strive to foster an environment of innovation and investment. Our actions further three policy priorities: <u>freeing additional spectrum</u>, removing barriers to infrastructure deployment, and promoting robust competition.
>
> Across each of these priorities, we are pursuing innovative policy approaches, necessitated in part by the growing complexity of the wireless broadband environment. (Emphasis added)[9]

Recently, Roger Sherman, Acting Chief of FCC's Wireless Telecommunications Bureau recently wrote,

> "As the expert agency on communications, it is the FCC's role to examine how we regulate the industry, and address unnecessary regulations when possible. In this case we have an outdated rule on our books that has been overtaken by advances in technology. If the technological justification for our existing prohibition is no longer valid, then it is our responsibility to examine ways to update and modernize the rules through an open and transparent rulemaking process." [10]

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[9] Remarks of Ruth Milkman, Chief, Wireless Telecommunications Bureau, FCC at Georgetown Center for Business and Public Policy and PCCA Workshop: "Optimal Coevolution of Mobile Broadband Technology and Spectrum Policy", June 14, 2013 (http://www.fcc.gov/document/wtb-chief-ruth-milkman-remarks-georgetown-spectrum-policy-workshop)

[10] http://www.fcc.gov/blog/fcc-and-inflight-mobile-wireless-services

In the case of frequencies greater than 95 GHz there is now no "technological justification for (the Commission's) existing prohibition". We ask that the Commission commit to Mr. Sherman's statement and make provisions to "update and modernize the rules through an open and transparent rulemaking process", one that is timely with respect to the development speed of today's technology – "Internet speed".

STATUS QUO

As stated previously, most commercial use of frequencies above 95 GHz are forbidden due to the present lack of service rules for either licensed or unlicensed use.[11] A waiver or petition for rulemaking is thus needed to gain access to spectrum. The Commission, unfortunately, has often had a slow record with dealing with innovative technologies and new bands. Many of the delays of new technologies and new bands have been related to difficult questions about possible harmful interference to incumbents in nearby bands. For example the PCS H block deliberations lasted more than a decade. The AWS-3/"M2Z" deliberations lasted 5 years and were never even formally resolved as the proponent disappeared in bankruptcy due to inability to fund its operations with no resolution of the FCC issues.

The Commission itself has acknowledged in the *Wireless Innovation Inquiry* the impact of delays in its deliberations on new technology stating,

> "(W)e are aware that Commission policies and processes can also hinder the progress of innovation and investment. At times, we have seen innovators subjected to lengthy regulatory processes - such as debates over what constitutes harmful interference or how to fit a new spectrum use within our framework of rules - that can be an obstacle to progress in the wireless arena."[12]

While serving on the Commission, former Commissioner Copps wrote

> There should be no doubt that facilitating further innovations in wireless technologies and services is absolutely crucial to our nation's prosperity and well-being in the Digital Age. We look to industry for much of that. But visionary public policy should always be the handmaiden of private enterprise. That's how we grew this country. Now, once again, we must learn to harness all our national resources for innovation and growth…

[11] 47 U.S.C. §301

[12] Fostering Innovation and Investment in the Wireless Communications Market, GN Docket Nos. 09-157, 09-51, Notice of Inquiry ("*Innovation NOI*"), FCC 09-66 (released Aug. 27, 2009) at para. 5 (http://fjallfoss.fcc.gov/edocs_public/attachmatch/FCC-09-66A1_Rcd.pdf)

> Wireless technologies and services are not just ends in themselves. These are things that will be called on to help solve many of the critical challenges facing our country—improvements in health care through telemedicine and patient monitoring devices; energy conservation through "smart grids;" education by bringing classrooms to eager learners wherever they may be; and public safety by enhancing the capabilities of our first responders, just to name a few. As we enable wireless technologies and services, we enable America to meet and master these many challenges.[13]

Former Commissioner McDowell has acknowledged the policy goal of trying to attract private capital and not discouraging investment,

> The Commission's longstanding policy to allow competitive market forces, rather than command-and-control regulations, to foster the development of and investment in wireless networks and services has led to remarkable advances. Thus, I hope that we will proceed with care; mindful that any future action we consider should aim to attract more private investment capital, rather than deter it.[14]

A recent informal MSS poll of communications attorneys experienced with innovative wireless issue on how long it would take to get a petition for technology >95 GHz adopted with rules resulted in a range of 2-5 years being stated, with most responses at the high end.

In his comments to the *Wireless Innovation Inquiry*, Mitchell Lazarus, a private attorney who often practices before FCC on issues related to innovative technology, wrote

> "The Commission's Rules are based largely on the technologies in place when they were written. New radio-based technologies often fail to satisfy those rules. The more novel an innovation, the less likely it is to comply. In consequence, a new wireless technology may need a Commission rulemaking or a waiver before it can reach the market. Technical proceedings in general, including those to authorize new technologies, have been dismayingly slow. I am not primarily concerned here with proceedings in which the opposition establishes a credible threat of harmful interference to incumbent operations. …These delays are an obstacle to innovation. Often a radically new technology comes from a small, privately-funded start-up. Its only product may be the one awaiting Commission approval. These companies may lack the resources to survive a lengthy FCC proceeding. "[15]

This is why it is urgent for FCC to adopt procedures that are innovation friendly for the spectrum >95 GHz, a "green field" area where there are no difficult interference issues with respect to FCC-licensed incumbents because there aren't any! The only incumbent users are passive services and federal

[13] Statement of Commissioner Michael J. Copps, *Innovation NOI*
[14] Statement of Commissioner Robert M. McDowell, *Innovation NOI*
[15] Comments of Mitchell Lazarus, GN Docket 09-157 at p. 2-3 (http://apps.fcc.gov/ecfs/document/view?id=7020039921)

government users and these can be protected through long standing NTIA coordination procedures or a variant of the 70/80/90 GHz accelerated coordination that FCC and NTIA agreed to in the context of those bands.

Some products are already being sold with transmitters at frequencies >95 GHz, however the legal status of these products is ambiguous.[16] Generally these products are noncommunications products and probably could meet the definition of ISM products although the present Part 18 rules presume high power heating applications and only allow a small portion of the spectrum. The sale of either communications products or security-related products for outdoor would cause a more direct confrontation with Commission's rules or lack of rules for these frequencies. It is reasonable to presume that the legal status of products >95 GHz and the expected delay for FCC rulemaking consideration based on past precedents are a key deterrent for capital formation for US entities interested in this technology.

In recent reply comments in another proceeding, Battelle Memorial Institute stated

> Battelle is currently involved in the development of a technology solution that will for the first time permit spectrum in the 102-109.5 GHz band (which is allocated for non-government fixed and mobile use), to be used to meet the growing demand for commercially-viable, high-bandwidth, low-latency, point-to- point communications. Battelle anticipates that it soon will petition the Commission to amend its rules to facilitate use of the 102-109.5 GHz band, employing a regulatory regime modeled on that currently applied to the 71-76 GHz, 81-86 GHz, 92-94 GHz and 94.1-95 GHz bands (collectively, the "70/80/90 GHz Band").[17]

There are currently 15 FCC experimental licenses for frequencies greater than 95 GHz.

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[16] Here a URL's for some noncommunications products now being sold >95 GHz: http://www.teraview.com/, http://www.picometrix.com/pico_products/terahertz_tr4000.asp,
https://www.advantest.com/US/products/Terahertz/WEBDEV004885
http://www.emcore.com/terahertz-thz-frequency-domain-spectrometer/
http://www.z-thz.com/index.php?option=com_content&view=article&id=51&Itemid=59

[17] Reply comments of Battelle Memorial Institute, Docket 13-84, November 11, 2013 at p.

FOREIGN COMPETITORS AND "STATE CAPITALISM"

On November 8, 2013, Chairman Wheeler stated at an open FCC forum

> "We're pro-America. We're pro how do you use spectrum efficiently for the common good of this nation to drive economic growth and to make sure we maintain world leadership in the application of spectrum delivered services."[18]

Thus the Chairman has identified driving economic growth and maintaining world leadership as key goals. The US and FCC have been a strong advocate of independent regulators in telecom[19], but the degree of CTUAL independence varies from country to country. FCC itself has no role in telecom R&D other than approval of experimental radio licenses. It is not involved in "picking winners and losers" in the R&D stage of technology by making R&D funding choices. However, this is not always the case in other countries.

On October 14, 2013 the Karlsruhe Institute of Technology announced wireless data transmission at a world-record rate of 100 gigabits per second.[20] This test involved a 20m indoor link but the announcement also mentioned that a few months earlier they had transmitted a data rate of 40 gigabits per successfully over a distance of one kilometer from one high-riser to another in the Karlsruhe City center. This project was

> "was funded with a total budget of EUR 2 million by the Federal Ministry of Education and Research (BMBF) under the program 'Broadband Access Networks of the Next Generation'. Apart from the research institutions of Fraunhofer IAF and KIT, the industry partners Siemens AG, Kathrein KG, and Radiometer Physics GmbH participated in the project."

This is a typical pattern in our national competitors. National government funding is combined with private sector funding in technical areas that are targeted. Those working in such targeted fields do not face the same regulatory uncertainty that US firms and US investors face with technology that needs nonroutine approvals from FCC. Indeed, since the European regulators already restrict entry on new technologies for cellular services and even cordless telephones, it is likely that such regulators will restrict

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[18] Statement of Chairman Wheeler at Learn Workshop to Discuss Unlicensed Spectrum Issues, November 8, 2013 (https://www.fcc.gov/events/learn-workshop-discuss-unlicensed-spectrum-issues)

[19] http://www.fcc.gov/encyclopedia/development-initiative

[20] Karlsruhe Institute of Technology Press Release 129/2013, "World Record: Wireless Data Transmission at 100 Gbit/s", October 14, 2013 (http://www.kit.edu/visit/pi_2013_14082.php) (See also http://eandt.theiet.org/news/2013/oct/wireless-record.cfm)

entry to US technology to frequencies above 95 GHz unless it is developed early enough to be attractive on European standards organizations. However, the lack of predictable access to home markets along with doubts about foreign markets are a powerful deterrent to private R&D funding – the only funding US firms have access to.

While more federal R&D funding of commercial communications technologies R&D might help this situation, it is unlikely for a variety of reasons. But increased FCC timeliness and transparency in dealing with technology above 95 GHz could help level the playing field with our foreign competitors.

SECTION 7

In his address at Carnegie Mellon University on July 18, 2012 , Commissioner Pai stated

> "If a company wants to market a new mobile device, it needs the FCC's approval.
>
> If a company wants to purchase another firm's spectrum licenses, it needs the FCC's approval. If a company wants to provide a new wireless service, it needs the FCC's approval. And if a company finds that there isn't any spectrum available and proposes the reallocation of inefficiently used spectrum, it needs the FCC's approval.
>
> Given these responsibilities, the FCC must act with the same alacrity as the industry we oversee. That's not to say we should rush to regulate, <u>but delays at the Commission have substantial real-world consequences: new technologies remain on the shelves; capital lies fallow; and entrepreneurs stop hiring or, even worse, reduce their workforce as they wait for regulatory uncertainty to work itself out."</u> (Emphasis added)[21]

In the same address, Commissioner Pai summarized succinctly the thrust of Section 7:

> Looking at that provision, the message from Congress is clear: The Commission should make the deployment of new technologies and new services a priority, resolving any concerns about them within a year.[22]

Now Section 7 is not a perfect piece of legislation. The exact context of the 1 year deadline is not entirely clear. But it clearly is the "law of the land" and the Commission has been avoiding it for 30 years since its passage. If the Commission has misgivings about the practicality of the current provisions of

[21] Remarks of FCC Commissioner Ajit Pai, "Unlocking Investment and Innovation in the Digital Age: The Path to a 21st-Century FCC", Carnegie Mellon University, Pittsburgh, PA, July 18, 2012 (http://www.fcc.gov/document/remarks-commissioner-pai)
[22] *Ibid*.

Section 7, an appropriate course of action would be to request a legislative change as the Commission does on a regular basis for other provisions of the Act.

Is Section 7 practical? Corporate mergers subject to FCC review are complex proceedings and have no similar statutory timeliness standard for FCC consideration. Yet the Commission has clear procedures and schedules for such reviews. The Office of General Counsel's Transaction Team

> "has … developed an informal timeline[23] to ensure that most applications are processed within 180 days after the Commission has sought comment from the public. The timeline is intended to promote transparency and predictability in the Commission's process."[24]

While the "180 days" is defined on a somewhat "elastic scale", a review of actual experience in reviewing mergers shows that most reviews are completed in less than 1 year from initial filing to FCC determination. Are these simpler than Section 7 "new technology" determinations"? A review of these actions by the Transaction team shows that most were extremely contentious and many involved thousands of pages of comments. Yet without statutory mandate the Commission consistently resolved them in less than a year because they were important.

Similar to the deadline of Section 7, Section 10(c) of the Communications Act[25] has a 1 year deadline for the Commission determining if it should forebear from regulating a Title II service. Similar to the case of merger review the Commission has established an "informal guideline"[26] with steps and schedules for handling Section 10(c) reviews. The diagram below is from the Commission's website and outlines how this timeline works:

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23 "Informal Timeline for Consideration of Applications for Transfers or Assignments of Licenses or Authorizations Relating to Complex Mergers" (http://www.fcc.gov/encyclopedia/informal-timeline-consideration-applications-transfers-or-assignments-licenses-or-autho)

24 http://www.fcc.gov/encyclopedia/transaction-team-office-general-counsel

25 47 U.S.C. 160(c)

26 http://transition.fcc.gov/wcb/cpd/forbearance/timeline.html

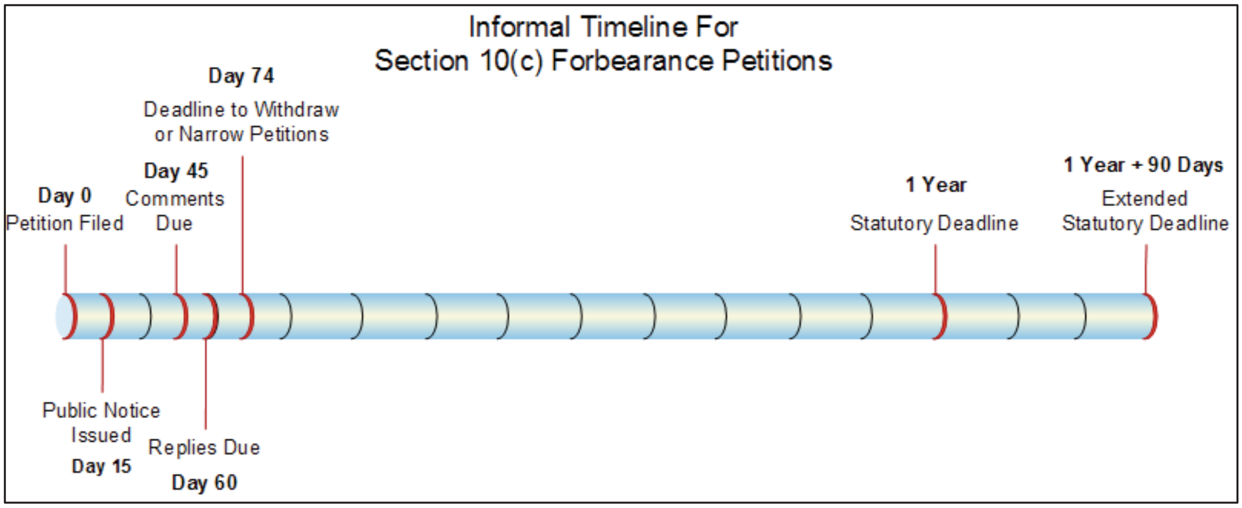

Figure 1: FCC's informal timeline identifies the stages of review a forbearance petition

In the table below, we compare the provisions of Sections 7(b) and 10(c) of the Communications Act. While admittedly none of our staff are admitted to the bar and have been testinged on the issue of "statutory construction", it would appear that in both cases Congress intended the Commission to act in a timely way.

Comparison of Sections 7(b) and 10(c)

Section 7(b)	Section10(c)
The Commission shall determine whether any new technology or service proposed in a petition or application is in the public interest within one year after such petition or application is filed. If the Commission initiates its own proceeding for a new technology or service, such proceeding shall be completed within 12 months after it is initiated.	Any telecommunications carrier, or class of telecommunications carriers, may submit a petition to the Commission requesting that the Commission exercise the authority granted under this section with respect to that carrier or those carriers, or any service offered by that carrier or carriers. Any such petition shall be deemed granted if the Commission does not deny the petition for failure to meet the requirements for forbearance under subsection (a) of this section within one year after the Commission receives it, unless the one-year period is extended by the Commission. The Commission may extend the initial one-year period by an additional 90 days if the Commission finds that an extension is necessary to meet the requirements of subsection (a) of this section. The Commission may grant or deny a petition in whole or in part and shall explain its decision in writing.

CHICKEN OR EGG PROBLEM

Some may argue that technology >95 GHz is not commercially practical at this time and thus there is no need for timely FCC action on such technology independent of any mandate pursuant to Section 7. In this viewpoint FCC should wait until the technology is commercially practical which will happen on its own pace independent of any FCC action.

Let us first go back to the original purposes of the Commission in the 1934 Act:

> For the purpose of regulating interstate and foreign commerce in communication by … radio so as to make available, so far as possible, to all the people of the United States … a rapid, efficient, Nation-wide, and world-wide wire and radio communication service with adequate facilities at reasonable charges.[27]

Along with the provisions of §303(g)

> Except as otherwise provided in this chapter, the Commission from time to time, as public convenience, interest, or necessity requires, shall—
> …
> (g) <u>Study new uses for radio</u>, provide for experimental uses of frequencies, and <u>generally encourage the larger and more effective use of radio in the public interest</u>;[28] (Emphasis added)

Thus these longstanding provisions of the 1934 Act, that predate Section 7 by decades, do not envision an agency passively waiting for new proven technology to appear on its doorstep for final approval before marketing. Rather they envision a more proactive agency seeking to make “rapid” and “efficient” communications available nationwide and both “studying new uses” and encouraging “the larger and more effective use of radio in the public interest”. The large bandwidths available >95 GHz, even if existing purely passive bands are ignored regardless of whether they are actually used, permit an quantum jump in achievable radio data speeds. For example there is a band with existing coprimary fixed allocations at 102 -109.5 GHz that has 7.5 GHz bandwidth that should be capable of fiber optic-like speeds without the “sunk costs” of installed fiber. (While fiber optic cable is quite inexpensive on a per meter basis, installation costs in urban area can be quite high if new construction is needed quickly.)

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[27] 47 U.S.C. §151
[28] 47 U.S.C. §303(g)

Will we see consumer electronics at >95 GHz in the next 5 years? Probably not. But FCC was not created solely to look after consumer electronics. The purpose of Title III is to "maintain the control of the United States over all the channels of radio transmission; and to provide for the use of such channels"[29] (emphasis added), not to only provide for consumer electronics. It is interesting to note that the current ubiquitous Wi-Fi and Bluetooth came from spectrum regulatory decisions the Commission made in 1985 in the case of spread spectrum technology that was considered exotic and immature at the time.

In the definitive book of the history of Wi-Fi written by its pioneers, the role of proactive FCC policies is discussed:

> The most important institution that has triggered and influenced this early part of the development of Wi-Fi is the Federal Communications Commission, the US National Regulatory Agency. … The WLAN (wireless local area network) innovation is triggered by a formal change in the institutional environment, i.e., in the regulatory regime of the radio frequency spectrum. As a common pool resource the RF spectrum is managed by the government or designated agency (the NRA) on the national level and coordinated at the international level through the International Telecommunications Union, as a part of the UN.
>
> The main goal of the frequency management paradigm is to avoid harmful interference and to provide a fair allocation of the limited natural resource to a variety of uses and users, e.g. radio and television broadcasting, terrestrial and satellite communications, emergency services (police, fire, ambulance), the military and for astronomy research.
>
> At first glance the decision by the FCC to assign spectrum to applications for which no clear market demand was demonstrated appears strange, given that radio frequency spectrum is a resource in limited supply. The motivation has been one of regulatory reform, of reducing the rules and regulations set by the government, with the aim of providing the industry with more freedom to innovate.[30]

When the Wi-Fi pioneers started their deliberations in 1988 that would become the 802.11b/Wi-Fi standard, their anticipated product goals were computer-based cash registers for department stores and portable bar code scanners for warehouses. Fortunately due to the FCC's 1985 Docket 81-413 decision[31] they did not need the nonroutine FCC regulatory approvals that new technologies >95 GHz now face and the rest is history!

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[29] 47 U.S.C §301
[30] W. Lemstra, V. Hayes, J. Goenewegen, *The Innovation Journey of Wi-Fi*, 2011, p. 22
[31] Report & Order, Docket 81-413, May 9, 1985

>95 GHz technology now exists in many US manufacturers, most of whom have little contact with FCC because they cater to federal and scientific markets. The Appendix to these comments shows specification of products available from 9 American firms. There are no off-the-shelf transmitter systems available for the simple reason that use of transmitters at these frequencies is **illegal** under present FCC with the few narrow exceptions given above. Real manufacturers do not develop products that have no legitimate market.

It is the basic hypothesis of these comments that just as the easing of access to the ISM bands in 1985 and the easing of access to the 60 GHz band in 1995 both created real civil markets for what was perceived at the time as exotic technology and stimulated capital formation and R&D, so simplifying commercial access to spectrum >95 GHz. Will also simplify capital formation and lead to new products. As in the case of the ISM bands and the 60 GHz bands, the spectrum above 95 GHz is lying fallow now and there are no incumbent users to be protected except perhaps federal government users and passive sensing users that can be protected with NTIA coordination procedures as in the case of 70/80/90 GHz.

CONCLUSIONS

MSS urges the Commission to grant the IEEE-USA petition to presumptively declare technology above 95 GHz to be "new technology" because it clearly is new technology in the world of commercial communications and such a finding would meet the Congressional intent in the adoption of Section 7.

Should the Commission question the practicality of Section 7's 30 year old present provisions, the appropriate course of action is to request a legislative change, not to ignore the statute.

Alternatively, the Commission should clearly state how it intends to move the boundary of nonfederal government radio systems above 95 GHz, what criteria it will use, and what time schedule it will seek to use analogous to agency existing statements on merger/acquisitions approval and Section 10(c) forbearance requests. Such a proactive policy will stimulate capital formation for technical innovation and help maintain US leadership in commercial radio technology in the face of state capitalism approaches by our foreign competitors that minimize risk for their own firms as well as subsidizing their R&D.

/s/

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Part	Description	Frequency (GHz)	Gain (dB)	NF (dB)	P1dB (dBm)	Availability
ALH394	HEMT Low Noise Amplifier	92-96	17	5	5	Stock
ALH495 (-LN)	HEMT Low Noise Amplifier	80-100	18	4.3	3	Stock
ALH495 (-GB)	HEMT Gain Block Amplifier	80-100	18	4.8	3	Stock
ALH497 (-LN)	HEMT Low Noise Amplifier	80-100	17	4.2	0	Stock
ALH497 (-GB)	HEMT Gain Block Amplifier	80-100	17	4.9	0	Stock
ALH503 (-LN)	HEMT Low Noise Amplifier	80-100	16	4.2	0	Stock
ALH503 (-GB)	HEMT Gain Block Amplifier	80-100	16	4.9	0	Stock
ALH504 (-LN)	HEMT Low Noise Amplifier	82-102	18	4.1	3	Stock
ALH504 (-GB)	HEMT Gain Block Amplifier	82-102	18	4.8	3	Stock

Power Amplifiers

Part	Description	Frequency (GHz)	Gain (dB)	P1dB (dBm)	Psat(dBm)	Availability
APH482	HEMT High Power Amplifier	92-96	7.5	22	25	Stock
APH484	HEMT High Power Amplifier	93-95	10	21	23	Discontd
APH631	HEMT Power Amplifier	92-96	23	15	18	Stock
APH635	HEMT Power Amplifier	92-95	17	20	22	Stock

Mixers

Part	Description	RF Freq (GHz)	LO Freq (GHz)	IF Freq (GHz)	CL (dB)	Availability
MBH100	HEMT Schottky Diode Mixer	91-99	91-99	DC-3	12	Stock

Multipliers & Switches

Part	Description	Freq Out (GHz)	Freq In (GHz)	RF Input (dBm)	CG/CL/IL(dB)	Availability
SDH148	HEMT SPDT Switch	80-100	NA	NA	<3/IL	Stock
XDH150	HEMT X2 Multiplier	92-96	46-48	-5	3/CG	Stock

Figure 1: Current products of Northrop Grumman Systems Corp., Redondo Beach, CA (http://www.northropgrumman.com/BusinessVentures/Microelectronics/Products/Pages/WBandProducts.aspx)

Virginia Diodes, Inc.

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Custom Sources and Receivers

VDI offers a wide variety of transmit and receive systems covering the 70-2000 GHz spectrum. These systems incorporate VDI's frequency-extension and mixer components coupled with commercially available microwave oscillators and amplifiers.

Transmit systems are configured as:

a) AMC: Amplifier-Multiplier- Chains (AMC) requiring a Customer low frequency input signal, or

b) Tx: Transmitters (Tx) having the base frequency oscillator (or synthesizer) as an integrated part of the system.

Receiver systems are configured as:

a) MixAMC: Mixer-Amplifier-Multiplier- Chains (MixAMC) requiring a Customer low frequency local oscillator (LO) input signal, or

b) Rx: Receivers (Rx) having the base frequency local oscillator (or synthesizer) as an integrated part of the system.

Relevant Links

- Standard Amplifier/Multiplier Chains (AMCs)
- Standard Mixer/Amplifier/Multiplier Chains (MixAMCs)
- Reconfigurable THz Kit
- Waveguide Band Designation

Standard AMCs & MixAMCs have been developed to provide high performance frequency multiplication and downconversion for full waveguide band coverage. These systems can be used to extend traditional spectrum analyzers and signal generator into the THz and mm-wave ranges.

Transmit systems are designed for either high-power or broadband operation. High Power systems use VDI D-series X2 multipliers (ie D52, D100, etc) to achieve maximum multiplier efficiency and power handling. Full waveguide band transmit systems utilize VDI WRx2 and WRx3 multipliers having lower efficiency but broadband capability. VDI receiver systems incorporate broadband VDI sub-harmonic mixers (ie WR2.8SHM, WR1.5SHM, etc) with broadband local oscillator (LO) multiplier chains. A single-switch DC power supply & cable, electronic output power control (0-5 VDC input) and electronic input (TTL) AM modulation are standard features. System frequency and power is unique and built to customer specifications. VDI has built and delivered hundreds of custom transmit and receive systems to customer specifications.

Standard, re-configurable and broad-band THz AMCs are available. The customer can reconfigure the WR10-base or WR9.0-base system for operation to about 1THz. See details in table below.

Freq (GHz) Band	Base AMC	Input Frequency (Customer Supplied)	Output Stages & Bands	Specifications
70-330 GHz	WR-10	8-12 GHz	WR10, 5.1, 3.4	Info
82-1000 GHz	WR-9	9-14 GHz	WR9.0, 4.3, 2.8, 2.2, 1.5, 1.0	82-1100 GHz Starter Kit

Please review some example systems as presented in the table below. Systems are available for any band within the 70-2000 GHz spectrum. The examples shown are a small subset and present some general system photos, layout and details. Contact VDI today to discuss frequency bands, input and output RF powers, phase-locking, noise temperatures and other specifications.

Please review some of our systems by clicking on the appropriate links below (in Table).

Freq (GHz) Band	WR	AMC	Tx	MixAMC	Rx
50.5-75	WR-15	WR15AMC	Info	Info	Info
60-90	WR-12	WR12AMC	Info	Info	Info
75-110	WR-10	94GHzAMC WR10AMC	84/94GHzTx 93GHzModTx	100GHzMixAMC	Info
82-125	WR-9	WR9.0AMC	Info	Info	Info
90-140	WR-8	100GHzAMC WR8.0AMC	108GHzModTx	WR8.0MixAMC	Info
110-170	WR-6.5	140GHzAMC 145GHzAMC	160GHzTxRx 143GHzModTx	100GHzMixAMC WR6.5MixAMC	160GHzRxTx 140GHzRx
140-220	WR-5.1	WR5.1AMC	198GHzTx	WR5.1MixAMC	Info
170-260	WR-4.3	214GHzAMC 235GHzAMC	228GHzTxRx 205GHzTx 215GHzModTx	WR4.3MixAMC 210GHzMixAMC 214GHzMixAMC	Info
220-330	WR-3.4	320GHzAMC	260GHzTx 320GHzDualTx 325GHzTx	WR3.4MixAMC	228GHzRxTx 260GHzRx
265-400	WR-2.8	310GHzAMC	333GHzTx 300GHzTx 340GHzTx	320GHzMixAMC	333GHzRx 266GHzRx 300GHzRx
330-500	WR-2.2	WR2.2AMC	400GHzModTx	Info	440GHzRx
400-600	WR-1.9	Info	Info	Info	Info
500-750	WR-1.5	600GHzAMC 675GHzAMC	645GHzModTx 650GHzTx	610GHzMixAMC 650GHzMixAMC	Info
600-900	WR-1.2	840GHzAMC	Info	750GHzMixAMC	806.4GHzRx 874GHzRx
750-1100	WR-1.0	850GHzAMC	Info	Info	Info
900-1400	WR-0.8	Info	Info	Info	Info
1100-1700	WR-0.65	1.3THzAMC	Info	1.5THzMixAMC	1.5THzRx
1400-2200	WR-0.5	1.9THzAMC	Info	Info	Info

Figure 2: Currents products of Virginia Diodes, Charlottesville, VA
http://www.vadiodes.com/index.php?option=com_content&view=article&id=378

Document ID: SDI-002
Revision: 0.0

High Quality Standard and Custom Designed Microwave & Millimeterwave Products

SAGE Millimeter, Inc.

Model Number	Frequency Range (GHz)	Gain (dB)	Gain Flatness (±dB)	NF (dB)	VSWR (Typ)	Bias (V/mA)	Outlines
SBL-3333632530-KFKF-S1	36.0 to 40.0	25	1.5	3.0	2:1	+10.0/150	BG-C1, BG-N1, BG-W1
SBL-3333633530-KFKF-S1	36.0 to 40.0	35	2.0	3.0	2:1	+10.0/200	BG-C1, BG-N1, BG-W1
SBL-4034532545-2F2F-S1	40.0 to 45.0	25	1.5	4.5	2:1	+10.0/150	BG-C1, BG-N1, BG-W1
SBL-4034533545-2F2F-S1	40.0 to 45.0	35	2.0	4.5	2:1	+10.0/250	BG-C1, BG-N1, BG-W1
SBL-5035531850-1515-S1	50.0 to 55.0	18	1.0	5.0	2:1	+10.0/100	BG-C2, BG-N2, BG-W2
SBL-5035533550-1515-S1	50.0 to 55.0	35	1.5	5.0	2:1	+10.0/200	BG-C2, BG-N2, BG-W2
SBL-5536031850-1515-S1	55.0 to 60.0	18	1.0	5.0	2:1	+10.0/100	BG-C2, BG-N2, BG-W2
SBL-5536033550-1515-S1	55.0 to 60.0	35	1.5	5.0	2:1	+10.0/200	BG-C2, BG-N2, BG-W2
SBL-6036531850-1515-S1	60.0 to 65.0	18	1.0	5.0	2:1	+10.0/100	BG-C2, BG-N2, BG-W2
SBL-6036533550-1515-S1	60.0 to 65.0	35	1.5	5.0	2:1	+10.0/200	BG-C2, BG-N2, BG-W2
SBL-6537031850-1515-S1	65.0 to 70.0	18	1.0	5.0	2:1	+10.0/100	BG-C2, BG-N2, BG-W2
SBL-6537033550-1515-S1	65.0 to 70.0	35	1.5	5.0	2:1	+10.0/200	BG-C2, BG-N2, BG-W2
SBL-7137632055-1212-S1	71.0 to 76.0	25	2.0	5.5	2:1	+10.0/100	BG-C2, BG-N2, BG-W2
SBL-7137633555-1212-S1	71.0 to 76.0	35	2.0	5.5	2:1	+10.0/150	BG-C2, BG-N2, BG-W2
SBL-7537832555-1212-S1	75.0 to 78.0	25	2.0	5.5	2:1	+10.0/100	BG-C2, BG-N2, BG-W2
SBL-7537833555-1212-S1	75.0 to 78.0	35	2.0	5.5	2:1	+10.0/150	BG-C2, BG-N2, BG-W2
SBL-8138632555-1212-S1	81.0 to 86.0	25	2.0	5.5	2:1	+10.0/100	BG-C2, BG-N2, BG-W2
SBL-8138633555-1212-S1	81.0 to 86.0	35	2.0	5.5	2:1	+10.0/150	BG-C2, BG-N2, BG-W2
SBL-8539032555-1010-S1	85.0 to 90.0	25	2.0	5.5	3:1	+10.0/100	BG-C2, BG-N2, BG-W2
SBL-8539033555-1010-S1	85.0 to 90.0	35	2.0	5.5	3:1	+10.0/150	BG-C2, BG-N2, BG-W2
SBL-9039532555-1010-S1	90.0 to 95.0	25	1.5	6.0	2:1	+10.0/100	BG-C2, BG-N2, BG-W2
SBL-9039533555-1010-S1	90.0 to 95.0	35	2.0	6.0	2:1	+10.0/150	BG-C2, BG-N2, BG-W2
SBL-9531042555-1010-S1	95.0 to 100.0	25	1.5	6.0	2:1	+10.0/100	BG-C2, BG-N2, BG-W2
SBL-9531043555-1010-S1	95.0 to 100.0	35	2.0	6.0	2:1	+10.0/150	BG-C2, BG-N2, BG-W2
SBL-8031042560-1010-S1	80.0 to 100.0	25	2.0	6.0	2:1	+10.0/100	BG-C2, BG-N2, BG-W2
SBL-8031043560-1010-S1	80.0 to 100.0	35	3.0	6.0	2:1	+10.0/150	BG-C2, BG-N2, BG-W2

Figure 3: Currents products of SAGE Millimeter, Inc., Torrance CA
http://www.sagemillimeter.com/#!amplifiers/cq9g

SERIES AMP

Millimeter-Wave Technology & Solutions

millitech

Model Number	FLow	FHigh	Gain (typ.) (dB)	1dBCP (typ.) (dBm)	Psat (typ.) (dBm)	Connector	Current (A) (typ. at Psat)[4]	Input Voltage (V) (min-max)	Max RF Input Power (dBm)	Outline Drawing
AMP-12-02510	81	86	15 (13 from 84-86 GHz)	25.0@81.0GHz, 24.3@83.5GHz, 22.5@86.0GHz	27.7@81.0GHz, 27.3@83.5GHz, 25.9@86.0GHz	WR-12	1.4	7.5 – 9	16	Fig. 8
AMP-12-40100[1]	81	86	29	27.5@81.0GHz, 26.8@83.5GHz, 25.0@86.0GHz	30.2@81.0GHz, 29.8@83.5GHz, 28.4@86.0GHz	WR-12	*	7.5 – 9	*	Fig. 12
AMP-10-02440	81	86	9	17.5	20.5	WR-10	0.24	7.5 – 15	13	Fig.9
AMP-12-10020[6]	81	86	17.5	25.4	29.0	WR-12	0.39	14 – 18	*	Fig. 8
AMP-12-20020[6]	81	86	16.5	28.0	31.6	WR-12	0.77	14 – 18	*	Fig. 12
AMP-12-40020[6]	81	86	16.5	30.7	34.3	WR-12	1.54	14 – 18	*	*
AMP-12-02310	75	87	16	10	12.5	WR-12	0.20	7.5 – 15	*	Fig.8
AMP-10-02310	75	87	16	10	12.5	WR-10	0.20	7.5 – 15	*	Fig.9
AMP-12-02290	80	90	20	14	16	WR-12	0.25	7.5 – 15	3	Fig.8
AMP-10-02290	80	90	20	14	16	WR-10	0 .25	7.5 – 15	3	Fig.9
AMP-10-22350	84	92	35	14	17	WR-10	0.50	7.5 – 15	5	Fig.10
AMP-10-02150	91	95	9	*	22	WR-10	0.30	7.5 – 15	15	Fig.9
AMP-10-22190	91	95	30	*	22	WR-10	0.60	7.5 – 15	5	Fig.10
AMP-10-40080[1]	91	95	15	*	27	WR-10	*	*	*	*
AMP-10-03220	92	95	9	*	24.5	WR-10	0.70	7.5 – 14	15	Fig.14
AMP-10-03250	93	95	17	*	33	WR-10	6.00	8 – 8.5	15	*
AMP-10-10030[6]	90	96	15.0	24.7	29.0	WR-10	0.35	14 – 18	*	Fig.9
AMP-10-20030[6]	90	96	14.0	27.3	31.6	WR-10	0.70	14 – 18	*	Fig.14
AMP-10-40030[6]	90	96	14.0	30.0	34.3	WR-10	1.40	14 – 18	*	*
AMP-10-02370	92	96	14.5	17	20	WR-10	0.30	7.5 – 15	12	Fig.9
AMP-10-22380	92	96	33	17	20	WR-10	0.60	7.5 – 15	5	Fig.10
AMP-10-22360	84	98	38	13	16	WR-10	0.50	7.5 – 15	5	Fig.10
AMP-10-22300	92	98	40	14	17	WR-10	0.50	7.5 – 15	5	Fig.10
AMP-10-03230	92	98	19	16	19	WR-10	0.60	7.5 – 14	5	Fig.14
AMP-10-02260	90	99	20	13	16	WR-10	0.30	7.5 – 15	5	Fig.9
AMP-10-10040[6]	75	102	15	18.0	23	WR-10	0.21	14 – 18	*	Fig.9
AMP-10-20040[6]	75	102	14	20.5	25.5	WR-10	0.42	14 - 18	*	Fig.13
AMP-10-03240	75	110	16.5@75GHz, 12.5@95GHz, 11.5@110GHz	*	16.0@75GHz, 15.5@95GHz, 16.0@110GHz	WR-10	0.56	7.5 – 15	10	Fig.13
AMP-10-02130	75	110	17.0@75GHz, 12.5@95GHz, 12.0@110GHz	*	13.5@75GHz, 12.5@95GHz, 13.5@110GHz	WR-10	0.23	7.5 – 15	10	Fig.9
AMP-08-40110	105	115	20	*	18.5@110GHz	WR-08	*	7.5 – 9	*	*
AMP-08-02450	90	125	13@90GHz, 12@110GHz, 8.5@125GHz	*	12.5@90GHz, 13.5@110GHz,	WR-08	0.26	7.5 – 15	10	Fig. 11

Figure 4: Current Products of Millitech, Inc., Northampton, MA
(http://www.millitech.com/pdfs/specsheets/IS000034-AMP.pdf)

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COMMERCIAL PRODUCTS

GaN Power Amplifiers (Not AS9100 Certified)					
PART NUMBER	FUNCTION	FREQUENCY (GHz)	POUT (dBm)	GAIN (dB)	PAE (%)
BAL-WPA	Power Amplifier	70-105	20	15	5
WPA	Power Amplifier	70-100	18	15	7
G94-PA	Power Amplifier	90-95	27	14	15
G84-PA	Power Amplifier	79-85	27 (Est.)	15	15 (Est.)
G74-PA	Power Amplifier	68-80	27 (Est.)	15	15 (Est.)
GAN-TWA	Power Amplifier	0.1-40	29 (10 GHz)	12	13 (10 GHz)

Sb DIODE DETECTORS						
PART NUMBER	FUNCTION	FREQUENCY (GHz)	SENSITIVITY (V/mW)	RJ (kOhm)	DATA	CAD FILES
V1A	Detector Diode MMIC	75-110	7	0.9	S-Parameters	.Dwg .Dxf .Gds .Stp .Ipt
DD2	Detector Diode MMIC	75-110	7	0.9	S-Parameters	.Dwg .Dxf .Gds .Stp .Ipt

InP Amplifiers

CAPABILITIES

- Ultra-High-Performance Integrated Circuits
- Architected 2D and 3D Materials
- Robust Computing and Communications
- Automated Knowledge Extraction

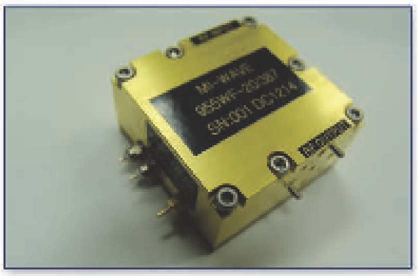
PRODUCTS & SERVICES

- Foundry Services
- Commercial MMIC Products
- Machine Shop

Figure 5: Current Products of HRL Laboratories, LLC., Malibu, CA
http://mmics.hrl.com

955 Series Amplifiers

MI-WAVE
Millimeter Wave Products Inc.



Standard Specification Chart Below
Other Bandwidths, Gain and dBCP available
Consult Mi-Wave for more specification needs.

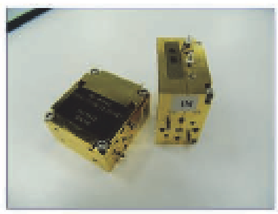
Description

Mi-Wave's 955 series microwave and millimeter wave amplifiers offer a wide variety of frequency ranges, bandwidths, gain and power outputs. Low Noise versions are now available. Frequencies from 8 GHz to 140 GHz.

Low cost production designs to meet the demanding needs of communications are also now available. High Power Outputs in the Millimeter Wave Frequencies up to +43 dbm. Please consult Mi-Wave for technical specifications and outline drawings

Features

- Low Noise
- High Gain
- Full Bandwidths
- High 1 db Comp. Points
- Wide Varity of Frequency Ranges
- 8 GHz to 140 GHz



Low Cost E-Band Amplifiers

Technical Specifications (typical)

Flow (GHz)		Freq. High (GHz)	Gain	dBCP 1db comp. point
17	-	40	20	20
18	-	23	23	30
18	-	26.5	19	26.5
18	-	28	18	26
18	-	32	22-16.5	23
18.5	-	26.5	11	28
20.0	-	40	18	19
23.5	-	29	18.5	27.5
25	-	27	26	28
25	-	33	14.5	26
26	-	31	21.5	32.5
27	-	35	16.5	22
28	-	31	21.5	33.5
28	-	31	20.5	26.5
28.5	-	31	18	28.5
30	-	40	36	19
30	-	40	15	30
30	-	40	13	29
31	-	35	15.5	30
31	-	35	37	28
32	-	36	17	33
33	-	36	13.5	29
36	-	40	11	26.5
36	-	42.5	13.5	25.5
37	-	45	20	21.5
40	-	45	9	28.5
40	-	60	17	12.5
41	-	46	13	30
43	-	46	16	21
50	-	66	22	15
71	-	76	23	16.5
76	-	81	17-21	12
80	-	90	20	16
90	-	99	20	12
92	-	96	14.5	17
75	-	110	14	10

Ordering Information

955 /___/___/___/___/___

Connector/Flange Designation
dBCP
Gain
FH
Flow

Millimeter Wave Products Inc. www.MIWV.com Tel. (727) 536-0033 Fax. (727) 536-0012 Email: sales@miwv.com

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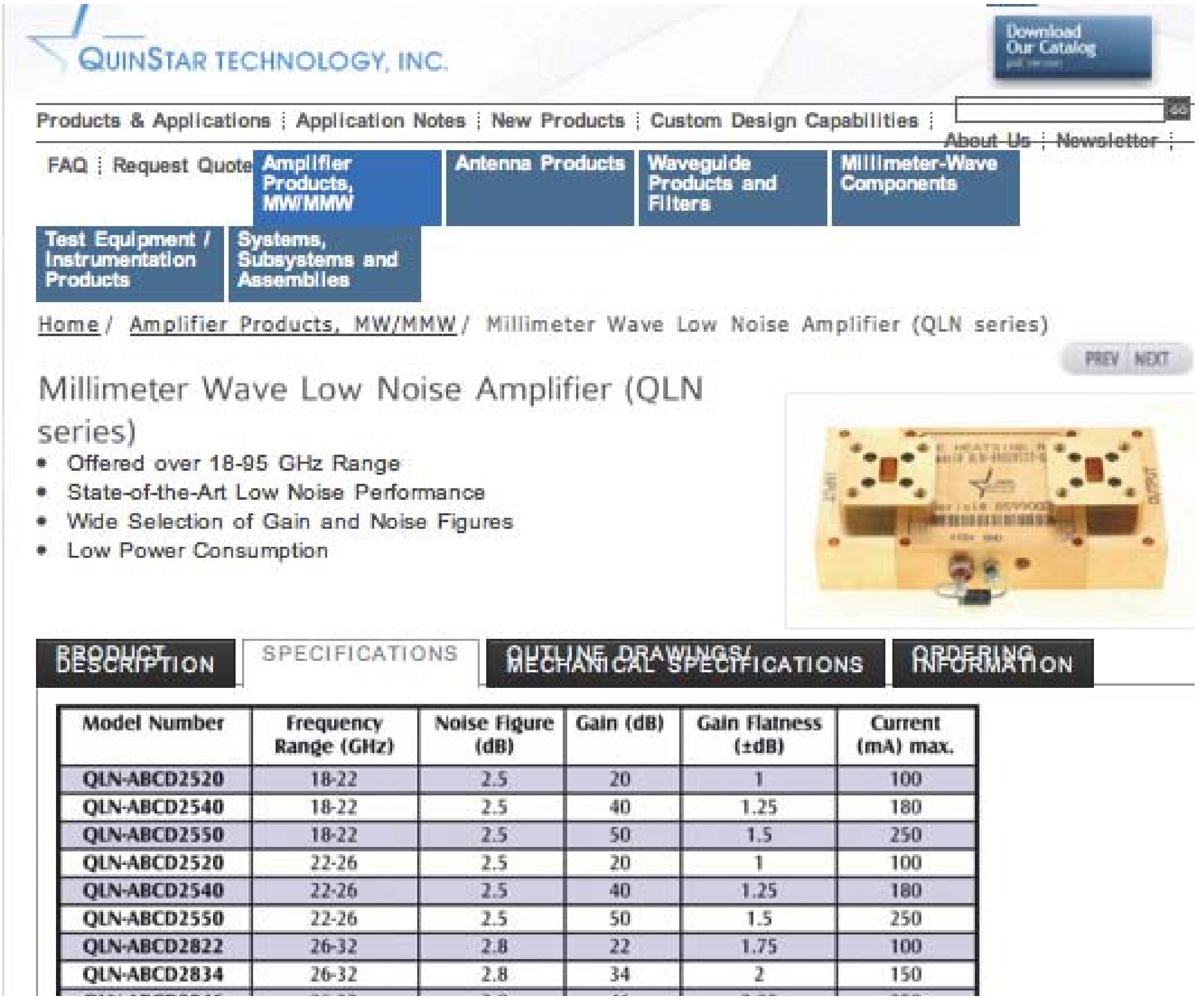
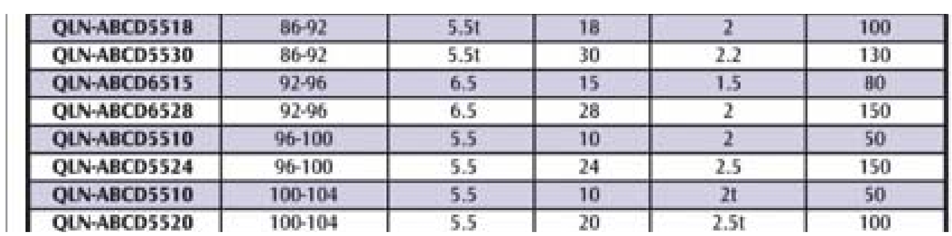
Figure 6: Current products of Millimeter Wave Products Inc., Largo, FL
http://miwv.com/drawings/955/MIWV_Series955.pdf



Model Number	Frequency Range (GHz)	Noise Figure (dB)	Gain (dB)	Gain Flatness (±dB)	Current (mA) max.
QLN-ABCD2520	18-22	2.5	20	1	100
QLN-ABCD2540	18-22	2.5	40	1.25	180
QLN-ABCD2550	18-22	2.5	50	1.5	250
QLN-ABCD2520	22-26	2.5	20	1	100
QLN-ABCD2540	22-26	2.5	40	1.25	180
QLN-ABCD2550	22-26	2.5	50	1.5	250
QLN-ABCD2822	26-32	2.8	22	1.75	100
QLN-ABCD2834	26-32	2.8	34	2	150

…



Model Number	Frequency Range (GHz)	Noise Figure (dB)	Gain (dB)	Gain Flatness (±dB)	Current (mA) max.
QLN-ABCD5518	86-92	5.5t	18	2	100
QLN-ABCD5530	86-92	5.5t	30	2.2	130
QLN-ABCD6515	92-96	6.5	15	1.5	80
QLN-ABCD6528	92-96	6.5	28	2	150
QLN-ABCD5510	96-100	5.5	10	2	50
QLN-ABCD5524	96-100	5.5	24	2.5	150
QLN-ABCD5510	100-104	5.5	10	2t	50
QLN-ABCD5520	100-104	5.5	20	2.5t	100

Figure 7: Current products of QuinStar Technology, Inc. Torrance, CA
(http://quinstar.com/amplifier/millimeter-wave-low-noise-amplifier-qln-series/)

Ducommun

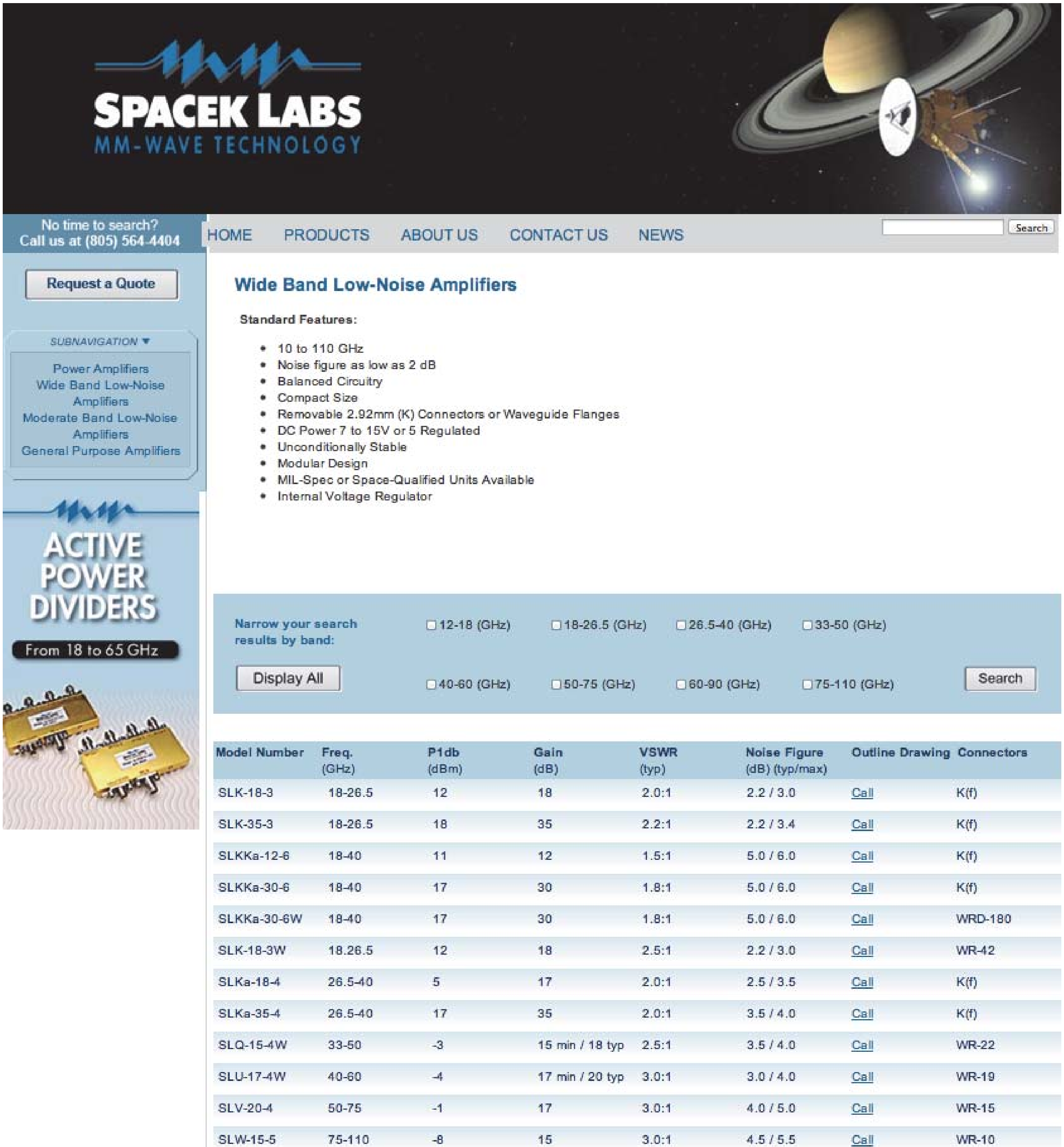
Ducommun LaBarge Technologies, Inc.
For more information, contact our inside sales team at
310.513.7200 or RFSales@ducommun.com
www.ducommun.com

SPECIFICATIONS

Full Waveguide Band General Purpose Amplifier							-40˚C to +50˚C
Model Number	Band	Frequency (GHz)	Noise Figure (Typ/Max, dB)	Gain, Flatness (Nominal, dB)	Current(mA) (Nominal @ 12V)	P1dB (dBm/Min)	Outline
AFB-DCK30GP -01	DC-K	0.01 - 20	4.5 / 7.0	26, +/- 6.0	450	20.0	WT-A-1
AFB-KUK30GP -01	KU & K	12.4 - 26.5	3.0 / 4.5	30, +/- 2.0	500	20.0	WT-A-1
AFB-KKA30GP-01	K & Ka	18 - 40	4.0 / 6.0	30, +/- 2.0	350	20.0	WT-A-1

Full Waveguide Band Power Amplifier						-40˚C to +50˚C
Model Number	Band	Frequency (GHz)	Power P1dB (Typ/Min, dBm)	Gain, Flatness (Nominal, dB)	Current(mA) (Nominal @ 12 V)	Outline
AFB-KA30HP -01 -02 -03	Ka	26.5 - 40	20.0 / 18.0	30, +/- 2.0	350	WT-A-1 WT-A-3 WT-A-11
AFB-Q30HP -01 -02	Q	33 - 50	20.0 / 18.0	30, +/- 2.0	500	WT-A-1 WT-A-11
AFB-U30HP -01 -02	U	40 - 60	14.0 / 12.0	30, +/- 2.0	300	WT-A-1 WT-A-11
AFB-V30HP -01 -02	V	50 - 75	15.0 / 12.0	30, +/- 3.0	200	WT-A-5 WT-A-11
AFB-E20HP -01 -02	E	60 - 90	14.0 / 12.0	20, +/- 3.0	250	WT-A-5 WT-A-11
AFB-W20HP-01 -02	W	75 - 100	13.0 / 10.0	20, +/- 3.0	250	WT-A-5 WT-A-11

Figure 8: Current products of Ducommun LaBarge Technologies, St. Louis, MO
(http://www.ducommun.com/pdf/AFB_Data_Sheet.pdf)



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ACTIVE POWER DIVIDERS
From 18 to 65 GHz

Wide Band Low-Noise Amplifiers

Standard Features:

- 10 to 110 GHz
- Noise figure as low as 2 dB
- Balanced Circuitry
- Compact Size
- Removable 2.92mm (K) Connectors or Waveguide Flanges
- DC Power 7 to 15V or 5 Regulated
- Unconditionally Stable
- Modular Design
- MIL-Spec or Space-Qualified Units Available
- Internal Voltage Regulator

Narrow your search results by band:

12-18 (GHz) 18-26.5 (GHz) 26.5-40 (GHz) 33-50 (GHz)

Display All

40-60 (GHz) 50-75 (GHz) 60-90 (GHz) 75-110 (GHz)

Search

Model Number	Freq. (GHz)	P1db (dBm)	Gain (dB)	VSWR (typ)	Noise Figure (dB) (typ/max)	Outline Drawing	Connectors
SLK-18-3	18-26.5	12	18	2.0:1	2.2 / 3.0	Call	K(f)
SLK-35-3	18-26.5	18	35	2.2:1	2.2 / 3.4	Call	K(f)
SLKKa-12-6	18-40	11	12	1.5:1	5.0 / 6.0	Call	K(f)
SLKKa-30-6	18-40	17	30	1.8:1	5.0 / 6.0	Call	K(f)
SLKKa-30-6W	18-40	17	30	1.8:1	5.0 / 6.0	Call	WRD-180
SLK-18-3W	18.26.5	12	18	2.5:1	2.2 / 3.0	Call	WR-42
SLKa-18-4	26.5-40	5	17	2.0:1	2.5 / 3.5	Call	K(f)
SLKa-35-4	26.5-40	17	35	2.0:1	3.5 / 4.0	Call	K(f)
SLQ-15-4W	33-50	-3	15 min / 18 typ	2.5:1	3.5 / 4.0	Call	WR-22
SLU-17-4W	40-60	-4	17 min / 20 typ	3.0:1	3.0 / 4.0	Call	WR-19
SLV-20-4	50-75	-1	17	3.0:1	4.0 / 5.0	Call	WR-15
SLW-15-5	75-110	-8	15	3.0:1	4.5 / 5.5	Call	WR-10

Figure 9: Current products of Spacek Labs Inc., Santa Barbara, CA
(http://spaceklabs.com/db/products/Search.php?SearchID=4&DatabaseID=1&producttype%5B%5D=Wide+Band+Low-Noise+Amplifier&Search.x=16&Search.y=20)

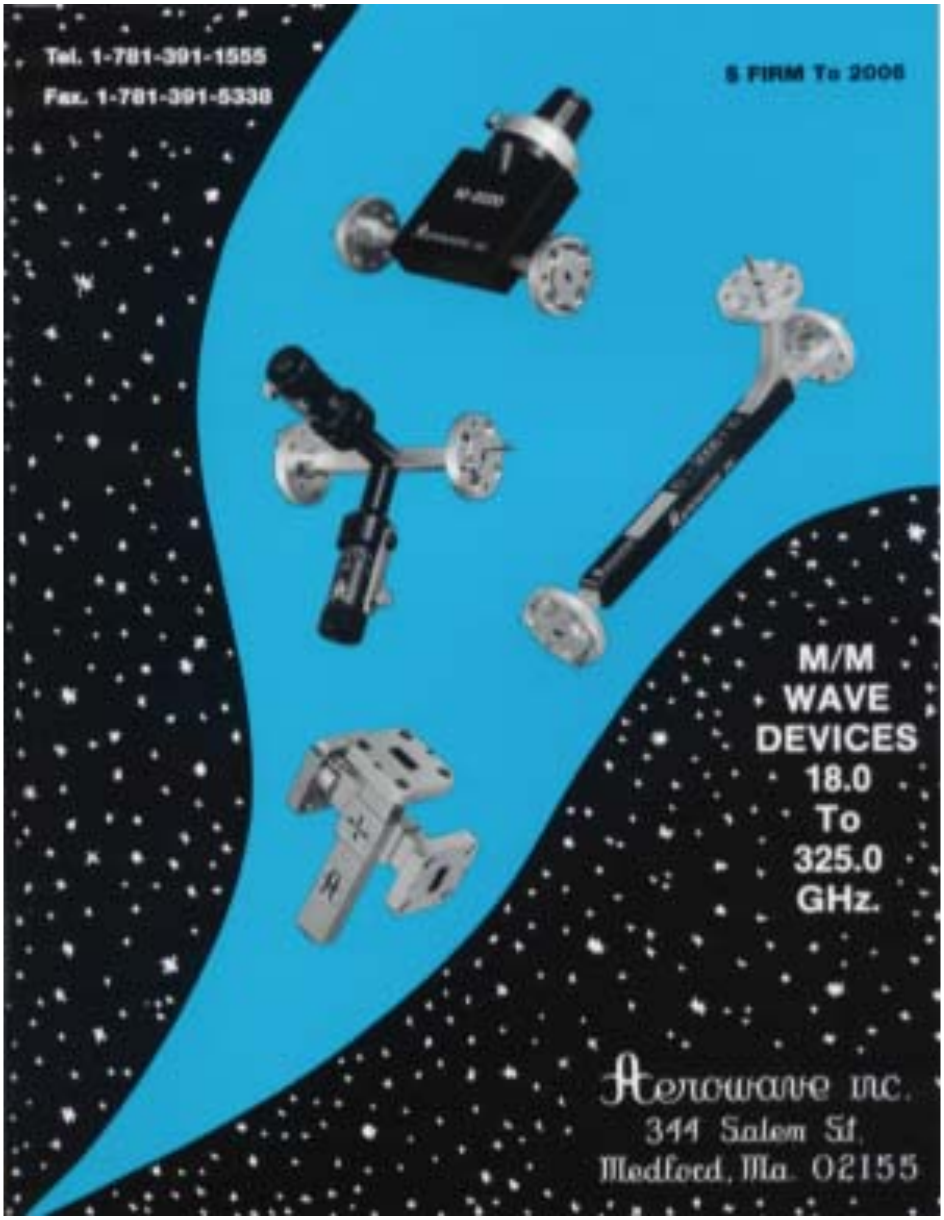

Figure 10: Current Products of Aerowave, Inc., Medford, MA
(http://www.aerowave.net/Product_Line.html)